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ABSTRACT

The purpose of this project was to construct a valid and reliable noncurriculum specific measure of integrated science process skills intended for use with middle school students. The major efforts in test development were focused on the refinements and modifications of the set of objectives and test items assessed by the existing Middle Grades Integrated Science Process Skills Test (Cronin and Padilla). Skills associated with planning, conducting, and interpreting results from investigations were delineated, and six objectives encompassing these skills were identified. There were 21 items judged to be the best measures of these objectives chosen for inclusion in the test. The POPS test was constructed in order to assess the process skills dealing with identifying experimental questions, identifying variables, formulating hypotheses, designing investigations, graphing data, and interpreting data. The readability of the test was assessed and an average grade level index of 6.8 was obtained. The POPS test is a reliable instrument for diagnostic and/or summative assessment in science classes or research studies. The test may be a useful means for classroom-based research, evaluation of instruction and learning, and curriculum validation in evaluation as well as assessing process skills competence of middle school students. (MVL)

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DEVELOPMENT OF THE PERFORMANCE OF PROCESS SKILLS (POPS) TEST FOR MIDDLE GRADES STUDENTS

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DEVELOPMENT OF THE PERFORMANCE OF PROCESS SKILLS (POPS) TEST FOR MIDDLE GRADES STUDENTS

Abstract

The purpose of this project was to construct a valid and reliable non-curriculum-specific measure of integrated science process skills intended for use with middle school students.

The major efforts in test development were focused on the refinements and modifications of the set of objectives and test items assessed by the existing Middle Grades Integrated Science Process Skills Test (Cronin and Padilla, 1986). Each objective and item was carefully analyzed to ensure that it was a valid representation of the intended process skills. Skills associated with planning, conducting, and interpreting results from investigations were delineated, and six objectives encompassing these skills were identified. Twenty-one items judged to be the best measures of these objectives were chosen for inclusion in the test. Modifications were made on the items in order to provide additional explanation for specific terms, i.e., the manipulated, responding, and controlled variables. The POPS test was constructed in order to assess the process skills dealing with identifying experimental questions (three items), identifying variables (six items), formulating hypotheses (three items), designing investigations (three items), graphing data (three items), and interpreting data (three items). The readability of the test was assessed using the FOG index, and the average grade level index of 6.8 was obtained. To establish content validity, objectives and items were submitted to a panel of reviewers. The responses of the four experts were consistent on almost all items in terms of indicating the correct answer and keying to a process skills objective. This concurrence of reviewers was taken as evidence of content validity and objectivity of scoring.

To examine test reliability and item indices, the POPS test was administered to middle school students in grades six through eight. A total of 1,402 students were involved in this field test. Total scores on the 21-item test for overall students ranged from 1 to 20 (Mean = 9.8, S.D. = 4.2). Total test reliability (KR-20) was .75. Item difficulty indices ranged from .28 to .79 with an average of .47. Item discrimination indices obtained by using the upper 27% and lower 27% of the sample group showed that 20 of the 21 items were above .30 with an average of .49. Point biserial correlation indices of item discrimination showed that 19 of the 21 items were above .30 with an average of .41. Each of these indices fell well within the acceptable range for a reliable test.

These results provide evidence of the reliability and validity of the test. The POPS test is a reliable instrument for diagnostic and/or summative assessment in science classes or research studies. The test may be a useful means in classroom-based research, evaluation of instruction and learning, and curriculum validation in evaluation as well as assessing process skills competence of middle school students.

DEVELOPMENT OF THE PERFORMANCE OF PROCESS SKILLS (POPS) TEST FOR MIDDLE GRADES STUDENTS

Purpose of This Study

The primary purpose of this project was to construct a valid and reliable non-curriculum-specific measure of integrated science process skills intended for use with middle school students.

At the middle school level, integrated science process skills such as identifying experimental questions, indentifying variables, formulating hypotheses, designing investigations, graphing and interpreting data are a vital aspect of meaningful science laboratory activity. These process skills represent the rational and logical thinking skills required in the process of problem solving in science. Few paper and pencil instruments to assess the process skills performance for middle grades students exist; thus, the present development took place.

The new test could serve either as an alternate and equivalent process skills test or enlarge the pool of available items for process skills assessment in middle school grades. This test could be used for diagnostic or summative assessment in science classes or research studies in ways such as the following:

1. Assessing the process skill competency level possessed by students
2. Assessing the student acquisition and progress measured by process skill performance
3. Evaluation of the effectiveness of certain instructional strategies, teaching skills, curriculum materials or modules on the development of process skills in students
4. An alternative to a practical laboratory procedure as a way to assess process skill performance

Background and Need for Study

Development of science process skills in students has been considered to be one of the major goals of science education (e.g., Gagne, 1965; Hernon, 1970; Neie, 1972; Okey, 1972; Padilla, 1980). In the past quarter century, a significant feature of most of the science curriculum development was a major shift of emphasis away from the teaching of science as a body of established knowledge toward science as a human activity, with increasing emphasis on experience of the processes and procedures of science (Hodson, 1988). The acceptance of process learning has created a need for measures of process skill performance.

Since the 1960's, as lagging behind the curriculum development which emphasizes the process of science, a number of paper and pencil measures have

been developed to assess science process skills performance. Initially, these efforts were aimed at the assessment of process skills associated with specific curricula such as the Science--A Process Approach (SAPA), the Science Curriculum Improvement Study (SCIS), and the Biological Science Curriculum Study (BSCS) (BSCS, 1962; Walbesser et. al., 1965; Fyffe, 1972; Burns, 1972; Riley, 1972; McLeod et. al., 1975; Ludeman, 1975).

In an attempt to separate a process skills test from a specific curriculum, several efforts have been done. Some have focused on measuring all science process skills including both integrated and basic process skills (e.g., Tannenbaum, 1968). Others were developed to measure a set of the basic process skills for upper elementary and lower secondary school students (Molitor and George, 1976; Padilla, Cronin, and Twiest, 1985). Recently, several attempts have been made to measure the integrated science process skills (Dillashaw and Okey, 1980; Tobin and Capie, 1982; Burns, Wise, and Okey, 1983; McKenzie and Padilla, in press; Cronin and Padilla, 1986). Most of these existing integrated process skills tests are geared primarily for upper secondary school students and contain items which require specific knowledge and/or well developed reading skills. Few tests of integrated process skills can be found suitable for middle school students; e.g., Cronin and Padilla (1986) developed the Middle Grades Integrated Process Skills Test (MIPT) intended for use with the grades 6-9 students.

In view of the continued need and relative scarcity of integrated process skills tests for middle school students, the present development of the Performance of Process Skills (POPS) Test has taken place. The following criteria were outlined for the test:

1. A measure of the integrated science process skills associated with the serial process of science experimentations such as identifying experimental questions, identifying variables, formulating hypotheses, designing investigations, graphing and interpreting data, and indeed assessing the thinking skills besides specific knowledge in the procedures

2. A non-curriculum-specific measure and content-free test items which are referenced to a general content domain and do not require specific content knowledge in a particular context

3. Multiple opportunities provided to demonstrate competence on each process skill and a wide range of difficulty of items addressing each process skill

4. Appropriate amount of reading and reading difficulty for middle school students (6-8) and avoiding the difficulty in understanding the meaning of specific terms such as manipulated, responding, and controlled variables

5. A multiple choice with four option response format

6. Appropriate number of test items and test length suitable for group administration less than 25 minutes; e.g., the test can be

administered either by itself or combined with other measures of student characteristics within one class period according to the purpose of its use and condition of testing in a practical sense

Procedures

The major efforts in test development were focused on the refinements and modification of the set of process skill objectives and test items assessed by other existing integrated science process skills tests; that is, the Middle Grades Integrated Science Process Skills Test (Cronin and Padilla, 1986). The MIPT test consists of 40 items designed to assess seven integrated process skills in science. They are identifying research questions (six items), stating hypotheses (six items), identifying variables (eight items), designing investigations (six items), contructing data tables (four items), constructing graphs from data (four items), and drawing conclusions (six items). Potential MIPT items were selected from the pool of test items, such as the Test of Integrated Process Skills (Dillashaw and Okey, 1980), the Group Test of Integrated Process Skills (Tobin and Capie, 1982) and the Test of Graphing in Science (McKenzie and Padilla, in press) and modified for use with middle school students, including new items.

Six process skill objectives were identified to form a basis for the POPS test items. They are identifying experimental questions, identifying variables, formulating hypotheses, designing investigations, graphing data, and interpreting data. These objectives were reviewed and found to be valid representations of the intended process skills. The objective of constructing data tables in the MIPT test was eliminated.

From the pool of the MIPT test items (total 40 items), the 21 items judged to be the best measures of the process skills identified were chosen for inclusion in the POPS test. Each item was carefully analyzed to ensure that the item measured the appropriate process skills and not specific knowledge in a particular procedure or science content. All multiple choice items employed four alternatives. The test contained at least three items for each objective. Five of the objectives were represented by three items, and the objective of identifying variables was represented by six items.

For the purposes of content validation and critique, four science educators with experience in both test construction and the integrated science process skills reviewed the test draft. The responses of the four reviewers were consistent on almost all items in terms of indicating the correct answer and keying to a process skill objective. This concurrence of raters was taken as evidence of content validity and objectivity of scoring. Revisions were made on those items where modifications were suggested. Modifications included changes in wording and sentence length in order to provide additional explanation for specific terms, i.e., the manipulated variable or the condition which was changed, the responding variable or the condition which is the measured outcome of the experiment, and the controlled variable or the condition that was kept constant. Figure 1 lists the process skill objectives of the POPS test and the number of test items corresponding to each objective.

The readability of the POPS test was assessed using the FOG index (Gunning, 1975). This index predicts the reading grade level necessary to read with 90 to 100% comprehension. On this scale, an average grade level index of 6.8 was obtained.

Field Test and Results

For the purposes to examine test reliability and item indices, the modified version of the POPS test was administered to middle school students in grades six through eight. A total of 1,402 students from a relatively rural school district in an eastern part of North Carolina were involved in this field test. The sample group involved was heterogeneous to provide representation across ability levels, socio-economic levels, gender, and race.

The descriptive statistics for the POPS test are shown in Table 1. The mean score and standard deviation for overall students on the 21-item test were 9.77 and 4.16 respectively. Total scores ranged from 1 to 20 with a standard error of measurement of 2.08. Total test reliability, as computed by the Kuder-Richardson formula (KR-20) was equal to .75. Item difficulty indices ranged from .28 to .79 with an average of .47. Item discrimination indices obtained by using the upper 27% and lower 27% of the sample group ranged from .27 to .71 with an average of .49 and were above .30 for 20 of the 21 items. Point biserial correlation indices of item discrimination ranged from .28 to .55 with an average of .41 and were above .30 for 19 of the 21 items. Each of these three test characteristics (reliability, item difficulty index, and item discrimination index) were well within the acceptable range for reliable tests (Payne, 1974). Based on these results from the field test, no further test revisions were considered necessary. Figure 2 summarizes descriptive characteristics of the POPS test.

For additional analyses, the entire POPS test was broken down into its six subscales of process skill objectives. The mean scores and standard deviations on the POPS total and each subscale by grade level and overall students are shown in Table 2. For overall students, correct response percentages were highest for the process skills of formulating hypotheses (59.0%) and were lowest for the process skills of graphing data (36.3%) and interpreting data (36.3%). These results indicated the difficulty levels of each process skill objective as a subscale of the POPS.

Conclusions and Educational Significance

The descriptive statistics obtained by field tests indicated that mean performance on the POPS test was comparatively low (9.8 out of 21). The standard deviation of 4.2 and a range of 20 indicated that the test differentiated students of differing ability. This observation was supported by the indices of reliability, item difficulty, and item discrimination which provided measures of the suitability of the test scores for differentiating student performance. Since each of these indices fell well within the acceptable range for reliable tests, the POPS test can be used by teachers to

obtain dependable student data as a basis for making decisions about individual students on item performance. In a research context, the test can be used to obtain measures to answer questions that require individual student performance to be differentiated or mean performance on the POPS items to be compared. The POPS measures are dependable for answering a range of research and evalution questions where performance of students, performance on items, or performance on different occasions need to be differentiated. The POPS test has applications for research and evaluation where teaching and learning integrated science process skills are a concern, if it is a valid measure of this ability.

Support was obtained for the content validity of the POPS test. Four science educators as reviewers agreed that the items measured the objectives they were designed to measure and that the scoring procedures proposed by the test designers were correct. This concurrence of raters was taken as evidence of content validity and objectivity of scoring. In addition to content validity, before the POPS test could be considered a highly valid measure of integrated science process skill ability, more validity data would be necessary, including factor analysis for construct validity and correlation analysis with interview tasks for criterion validity.

The data that has been gathered in this investigation provides evidence of the reliability and content validity of the POPS test. The search of available integrated science process skills tests showed the continued need and relative scarcity of a test geared to middle school students and not associated with any particular science curriculum. The development of the Performance of Process Skills (POPS) Test fills this void. This test could serve either as an alternate and equivalent process skills test or enlarge the pool of available items for process skills assessment in middle school grades. The 21-item paper and pencil test can be administered to groups of students to obtain measures of process skill acquisition for use by classroom teachers, researchers, and evaluators. The test is not specific to a given curriculum or content area; therefore, it may be used across the various disciplines of science. As well as assessing process skills competence of middle school students, the test may also be a useful means in classroom-based research, evaluation of instruction and learning, and curriculum validation in evaluation. The POPS test is a reliable instrument for diagnostic and/or summative assessment in science classes or research studies.

* Copies of the POPS test can be obtained from either author.

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Table 1

Descriptive Statistics for the POPS Test (21 Items)

Grade	Number	Mean	Standard Deviation	Reliability
6	252	8.72	3.65	.68
7	834	9.23	3.98	.73
8	316	11.63	4.36	.78
OVERALL	1402	9.77	4.16	.75

Table 2

Means and Standard Deviations for the POPS Test
by Process Skill Objective and Grade

Process Skill Objective	Grade 6th (N=252)	Grade 7th (N=834)	Grade 8th (N=316)	Total (N=1402)
	Mean (S.D.)			
P1. Identifying Experimental Questions (3)	1.51 (0.96)	1.49 (0.96)	1.80 (0.94)	1.58 (0.96)
P2. Identifying Variables (6)	2.33 (1.45)	2.52 (1.51)	3.32 (1.68)	2.67 (1.58)
P3. Formulating Hypotheses (3)	1.65 (0.97)	1.69 (0.98)	2.02 (0.90)	1.77 (0.97)
P4. Designing Investigations (3)	1.35 (1.02)	1.53 (1.04)	1.78 (0.99)	1.57 (1.04)
P5. Graphing Data (3)	1.00 (0.81)	1.01 (0.86)	1.31 (1.00)	1.09 (0.90)
P6. Interpreting Data (3)	0.89 (0.81)	1.02 (0.90)	1.42 (0.90)	1.09 (0.91)
Overall Skills (21)	8.72 (3.65)	9.23 (3.98)	11.63 (4.36)	9.77 (4.16)

Process Skill Objectives	Number of Test Items
P1. Identifying Experimental Questions: identify a reasonable question which can be tested in an experiment.	3
P2. Identifying Variables: given a description of an experiment, identify the manipulated, responding, and controlled variables involved in it.	6
P3. Formulating Hypotheses: given a description of variables involved in an experiment, select a reasonable hypothesis which is being or can be tested.	3
P4. Designing Investigations: given a hypothesis, select a suitable design for an experiment to test it.	3
P5. Graphing Data: given a description of an experiment and obtained data, identify a graph that represents the data correctly.	3
P6. Interpreting Data: given a description of an experiment and graphed results, describe the relationship shown on the graph or identify a graph that shows the relationship described.	3

Figure 1

The POPS Objectives and Number of Test Items

Process Skill Tested:	Identifying Experimental Questions Identifying Variables Formulating Hypotheses Designing Investigations Graphing Data Interpreting Data
Target Group:	Middle Grades 6-8
Number of Items:	21
Response Format:	Four Alternative Multiple Choice
Test Readability (FOG):	6.8
Time to Complete Test:	25 minutes
Discrimination Index:	.49 (Average) .27 to .71 (Range) 20 of the 21 items above .30
Difficulty Index:	.47 (Average) .28 to .79 (Range)
Reliability (KR-20):	.75
Total Test Score:	9.77 (Mean) 4.16 (S.D.) 1 to 20 (Range)
Standard Error of Measurement:	2.08

Figure 2

Summary Characteristics of the POPS Test